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CONSERVATION OF WASTES FROM THE SMALL-SCALE SLAUGHTER OF MEAT ANIMALS

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PURPOSE OF INVESTIGATION

The utilization of the offal[1] and shed blood from animals slaughtered in the large abattoirs and packing houses of this country leaves little to be desired. Waste is carefully controlled, and sanitation is safeguarded. The advantageous and sanitary disposal of the offal and blood from the large numbers of animals butchered on farms and in small retail establishments, however, constitutes in the aggregate a problem of some importance. The investigation reported in this circular was undertaken to develop a satisfactory method of disposal for this perishable refuse whereby the valuable nitrogen and phosphoric acid might be conserved for use as fertilizer.

EXTENT OF SMALL-SCALE SLAUGHTER

According to estimates and data recently compiled in this Department (*3*),[2] there is an annual slaughter of close to 18,000,000 cattle, sheep, and swine on the farms and ranges of the United States. It is estimated that 1,800,000 of these are cattle (beeves and calves), animals which yield comparatively large quantities of offal and blood. Figures 1, 2, and 3 show the distribution of the annual slaughter of cattle, sheep, and swine on farms and ranges in the United States.

By a conservative estimate the total quantity of fertilizing constituents, nitrogen and phosphoric acid, contained in the offal and shed blood from these animals amounts to more than 5,300 tons of pure

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[1] Offal and refuse as used in this circular mean inedible offal and inedible refuse.

[2] Italic numbers in parentheses refer to Literature Cited, p. 23.

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nitrogen (6,500 tons of ammonia) and about 1,900 tons of phosphoric acid (P_2O_5), or more than 4,100 tons of bone phosphate of lime. This estimate is based on data for the yields of offal and blood from farm animals of the several types, supplemented by analytical data on the chemical composition of the materials. These data were obtained on representative samples of offal and blood of cattle, sheep, and hogs brought from the abattoir of the Department's experiment farm at Beltsville, Md., and analyzed at the laboratory. Table 1 shows the number of animals slaughtered on farms and ranges in 1932, and

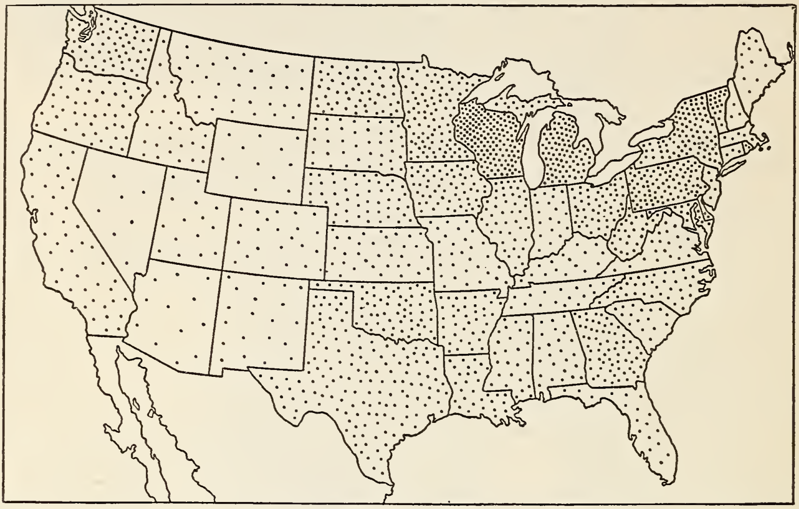

FIGURE 1.—Distribution of the annual slaughter of beef cattle and calves on farms and ranges. Each dot represents 1,000 animals slaughtered during 1932.

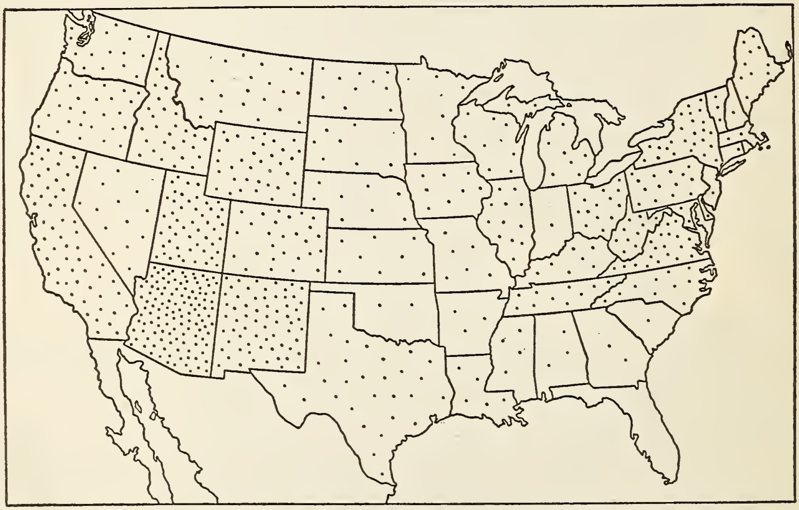

FIGURE 2.—Distribution of the annual slaughter of sheep and lambs on farms and ranges. Each dot represents 1,000 animals slaughtered during 1932.

the quantities of offal and blood yielded by animals of average weight of each class. Table 2 gives an estimate of the quantities of potentially valuable materials in the total offal and blood yielded by animals slaughtered on farms and ranges in 1932.

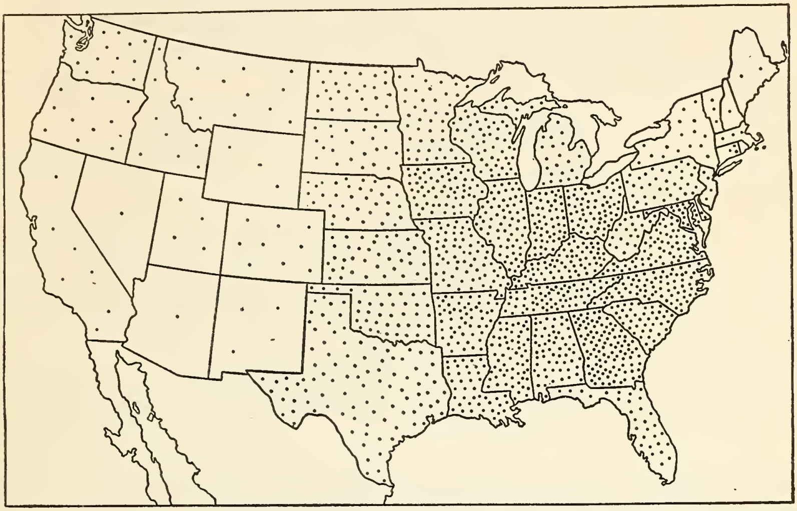

FIGURE 3.—Distribution of the annual slaughter of hogs and pigs on farms and ranges. Each dot represents 10,000 animals slaughtered during 1932.

In 1932 in addition to the animals slaughtered on farms and ranges it is estimated that approximately 7,800,000 farm animals were butchered in local (retail) establishments. Of these more than 3,500,000 were cattle (*3*).

TABLE 1.—*Number of animals slaughtered on farms and ranges in 1932 and estimated quantities of offal and shed blood yielded*

Class of animal	Animals slaughtered	Average live weight [1]	Estimated yield of shed blood		Estimated yield of raw offal [2]		Total raw products	
			Per animal	Percentage of live weight of animal	Per animal	Percentage of live weight of animal	Blood	Offal
	Number	*Pounds*	*Pounds*	*Percent*	*Pounds*	*Percent*	*Short tons*	*Short tons*
Beeves	722,000	754.4	25.65	3.40	98.8	13.1	9,260	35,667
Calves	1,078,000	194.1	7.55	3.89	25.4	[3] 13.1	4,069	13,691
Sheep and lambs	751,000	89.4	3.45	3.86	13.1	14.6	1,295	4,919
Hogs	15,170,000	231.8	8.00	3.45	19.0	8.2	60,680	144,115
Total	17,721,000						75,304	198,392

[1] Obtained from data compiled in the Bureau of Agricultural Economics (*3*)

[2] The raw offal from cattle comprises the skull, the feet from knee to hoof, and the inedible viscera after the contents of the digestive tract have been removed. The caul and intestinal fats are not here included as offal. The offal from sheep and lambs consists of the cleaned inedible viscera, the skull, and the mesenteric fats, but not the feet. The entire inedible viscera, including all except readily removable contents, but no bone material, and no intestinal fats suitable for lard making, comprise the offal from hogs.

[3] In view of the radically different styles of dressing veal on the farm, the percentage of live-weight yield of offal for calves is assumed to be the same as that for the mature cattle.

TABLE 2.—*Estimated quantities of potentially valuable material in the offal and shed blood from animals slaughtered on farms and ranges in 1932*

Class of animal	Raw material		Constituents of potential value					
			Fat, tallow, or grease [1]		Dry residue, representing fat-free offal, or dry whole blood [2]			
	Kind	Quantity	Total quantity	Percentage of raw offal	Total quantity	Percentage of raw material	Fertilizer constituents	
							Nitrogen (N)	Bone phosphate, $Ca_3(PO_4)_2$
		Short tons	*Short tons*	*Percent*	*Short tons*	*Percent*	*Short tons*	*Short tons*
Beeves	Offal	35, 667	5, 707	16. 0	7, 847	22. 0	811. 8	1, 979. 5
	Blood	9, 260	---------	---------	1, 945	21. 0	296. 3	14. 9
Calves	Offal	13, 691	2, 191	[3] 16. 0	3, 012	[3] 22. 0	311. 6	759. 9
	Blood	4, 069	---------	---------	814	20. 0	122. 1	6. 6
Sheep and lambs	Offal	4, 919	881	17. 9	836	17. 0	91. 7	209. 5
	Blood	1, 295	---------	---------	272	21. 0	41. 4	2. 1
Hogs	Offal	144, 115	21, 329	14. 8	24, 355	16. 9	1, 787. 0	1, 080. 9
	Blood	60, 680	---------	---------	12, 379	20. 4	1, 881. 1	97. 7
Total	Offal	198, 392	30, 108	---------	36, 050	---------	3, 002. 1	4, 029. 8
	Blood	75, 304	---------	---------	15, 410	---------	2, 340. 9	121. 3

[1] The total fat in the material as shown by analyses of the offal from beeves, lambs, and hogs. Data on quantities obtainable by rendering can be determined by deducting the quantities of fat left in the tankage.

[2] For convenience in estimating possible yields of tankage, cracklings, ordinary dried blood with 10 percent of moisture, etc., the data on the dry residues are for the entirely dry, fat-free substance. To estimate the yield of tankage of given composition that might be expected from lamb offal, for example, divide the percentage yield of dry residue (17) by the proportionate quantity of dry, fat-free residue in the given tankage. Accordingly the yield of open-kettle tankage containing 10 percent of moisture and 27 percent of fat that might be expected from the total offal of lambs would be 17 percent divided by (100–10–27) percent, or 17÷0.63, giving 27 percent. The corresponding percentage yield of fat recoverable as tallow from such rendering would then be 17.9−(27×0.27) percent, or 10.6 percent of the weight of offal.

[3] In view of the different methods of dressing veal, it is assumed that the composition of the offal from calves is the same as that from beeves. (See table 1, footnote 3.)

PRODUCTS FROM WHOLE STRICKEN OR CONDEMNED ANIMALS

Occasionally, as in the summer of 1934, catastrophic conditions arise, requiring the speedy slaughtering of many head of stock as an emergency measure. Many of the drought-stricken animals may be in such a state as to be unsuitable for human food; and the situation may be such as to make it expedient to send the whole carcass of the animal to the rendering tank.

In view of this the attempt has been made to obtain reliable data regarding the yields of marketable products to be expected on rendering the entire "empty" carcasses of the different classes of stock. By empty carcass is here meant the whole animal after the carcass has been opened and the contents of the digestive and excretory tracts removed. It is further assumed that in the case of slaughtered stock, the shed blood would be dried separately, and in the case of all except hogs, the hides or pelts also would be salvaged separately.

The results of actual tests, conducted by a manufacturer of dry-rendering equipment, on rendering whole animals, are here made available (table 3).[3]

Kindness of Paul I. Aldrich, editor of the National Provisioner.

TABLE 3.—*Reported yields of grease (or tallow) and cracklings obtained by dry rendering whole carcasses* [1]

Class of fallen or condemned animal [2]	Animals	Total weight	Yield, as percentage of total weight (whole carcass)	
			Grease or tallow	Pressed cracklings (dry-rendered tankage)
	Number	*Pounds*	*Percent*	*Percent*
Steers	8	6,808	17.04	21.97
Cows	10	5,147	11.27	23.49
Cattle	7	3,839	10.89	28.47
Sheep	68	2,989	20.74	26.13
Hogs	30	9,847	34.55	19.62
Work horses	8	6,715	10.05	28.85
Range horses	6	3,335	3.24	35.23

[1] The results of a series of tests conducted by the Allbright-Nell Co.

[2] Animals dead of disease—at least not slaughtered for human food. The 7 cattle are classed as condemned carcasses.

Data published in the National Provisioner for the yields of tallow or grease, and tankages, evidently obtained by direct-steam digestion rendering of the whole carcasses, for three classes of mature cattle, are assembled in table 4.

TABLE 4.—*Reported yields of tallow or grease and tankages obtained by direct-steam rendering of cattle (whole carcasses)*[1]

Class of cattle	Yield, as percentage of carcass		
	Tallow	Ordinary, old-process tankage	Concentrated tankage or "stick"
	Percent	*Percent*	*Percent*
Steers	19	16	10
Cows	10	11	8
"Canners"	12	14	10

[1] From the National Provisioner, Apr. 2, 1927, p. 33 (*1*).

An ultimate measure of the possible yields and composition of tankage, tallow, and dried blood that might be obtained, in the case of a mature dairy cow in medium flesh, is provided by very complete analytical data published by the Missouri Agricultural Experiment Station (*2*). In this study the blood and principal organs were carefully separated from the slaughtered animal; the rest of the carcass was further separated into constituent parts; and wherever practicable all parts were divided into their lean and fat, or bone, components. Each part was weighed, and analyzed in the chemical laboratory. It has been possible, therefore, by correlation of these data to reconstruct chemically and anatomically the animal as a whole; and to compute the maximum possible yields and composition of tankage, tallow, and blood obtainable. These computed yields and the theoretical composition of the tankage and dried blood are given in table 5. It has been assumed that the finished total tankage would contain 10 percent of moisture and 8 percent of fat, that the shed blood would be dried to 8 percent of moisture, and that there would be no destruction or loss of any substance other than moisture through evaporation.

TABLE 5.—*Computed yields and composition of dried blood and tankage and yield of tallow, obtainable through rendering the whole carcass of a dairy cow* [1]

Product	Computed yield [2]		Computed composition [2]					
	From 1,000 pounds live weight	Per 100 pounds of raw material to the tank	Moisture	Fat	Nitrogen	Crude protein (Nx6.25)	Bone phosphate of lime, $Ca_3(PO_4)_2$	Ash
	Pounds	*Pounds*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Dried blood [3]	7.8	--------	8.0	-------	14.3	89.4	0.7	3.3
Tallow or grease	158.0	20.73	--------	100.0	--------	--------	--------	-----
Mixed (total) tankage, dried	202.2	26.52	10.0	8.0	9.5	59.4	18.9	20.7
or								
Ordinary digester tankage, no tank water saved [4]	141.5	18.56	10.0	11.4	8.2	51.3	26.0	27.3

[1] These data were computed from the yields and chemical analyses reported in Research Bulletin No. 61 of the Missouri Agricultural Experiment Station (*2*). They refer to cow no. 63, a Jersey, about 6 years old, weighing 902 pounds, in medium condition of flesh, and dry.

[2] The yields and composition were computed on the basis of the whole "empty" animal including cleaned offal, after removal of the hide (5.66 percent of the live weight) and deducting the contents of the digestive and excretory systems (14.6 percent), assuming no loss of material other than evaporated water. The shed blood (3.5 percent) is considered separately.

[3] Whole blood, dried; not coagulated blood solids.

[4] Assuming evaporated tank water or "stick" to contain 10 percent of moisture and 15 percent of ammonia (12.34 percent nitrogen); and to amount to 30 percent of the total mixed tankage.

ADVANTAGES OF RENDERING

The advantages of cooking and rendering the waste parts of animals for the separation of the fat or grease are evident. The removal of fat, tallow, or grease increases the concentration of the nitrogenous and phosphatic constituents of the residue and thereby enhances the value of the rendered portion for either fertilizing or feeding purposes. Much fat in fertilizer material is objectionable, not only because the fat has no fertilizing property, but because it envelops and waterproofs the particles containing plant food, retarding their decay in the soil, and thus delaying the breaking-down of the material into available fertilizer. There is evidence, also, that much fatty or oily material in the soil may result in injury to growing plants. Of great importance, moreover, is the fact that thorough cooking sterilizes the waste materials and destroys parasites and disease organisms, making the tankage comparatively safe for further use. The separated fat, tallow, or grease has well-recognized market value, but this argument in favor of rendering has not the weight in small-scale operations that it has in large establishments, where the revenue derived from the sale of fats and greases is important.

DISPOSAL IN LARGE ESTABLISHMENTS

OFFAL

Several methods of rendering animal offal and fats to produce grease, oil, or tallow, yielding fertilizer or feeding tankage as by-products, have been used under various circumstances. In the early days of the meat-packing industry in this country, much of the rendering was done by prolonged boiling in open kettles. With the organization of the meat-packing industry into large units, rendering by direct steam digestion in closed tanks became the usual method of handling the inedible offal in the larger establishments. The hashed offal (and often bones as well) was cooked for 7 to 10 hours by saturated steam under a gage pressure of 35 to 45 pounds. By this method the oil and tallow were separated from the tissues and even large bones were softened. After the cooking is finished, in this type of processing, the contents of the tank are allowed to settle; the upper layer of melted fat is drawn off; the tank water (which is a solution of gluelike substance) is discharged into settling vats; and the hot, wet tankage is removed and pressed in hydraulic presses, yielding additional grease-bearing liquor. The tankage press cake after drying (and often grinding) constitutes the digester tankage of commerce. The tank water, after being freed from grease in the settling tanks, is sometimes evaporated and the concentrated residue, known as "stick" may be dried with the tankage. Costs and economies in drying "stick" in large-scale operations prior to 1921 have been studied and published *(9)*.

In the newer "dry" rendering process, which to a considerable extent has supplanted steam digestion in the largest plants, the offal, or other fatty material, does not come in direct contact with added steam or water. The raw material is cooked in steam-jacketed kettles, either at ordinary atmospheric pressure, or (in establishments provided with kettles operating on the autoclave principle) under more or less steam pressure. This stage of the cooking is continued long enough to soften and disintegrate the material; after which the vapor is drawn out of the kettles by suction—to facilitate the evaporation of moisture from the tissues. Steam in the kettle jackets is maintained at about 60-pound pressure. By this procedure, the moisture of the raw stock is evaporated completely, and after a time the material fries in its own grease. The liberated fat is drawn off in heated strainers (percolators), and that which adheres to the cracklings is removed by subjecting the material, while hot, to high pressure. The pressing, ordinarily, is carried out in expellers of the continuous screw type, although hydraulic presses are also in common use. The final product, a cracklings expeller cake, is generally more attractive than a corresponding tankage made by the older digester process, and most of it, if not all, is marketed as stock food.

BLOOD

In the commercial reduction of animal waste materials, the shed blood is usually collected and treated separately, because of the ease with which it can be converted into a marketable product, and also because the dried blood possesses a higher value as feed, or as an organic ammoniate fertilizer, than the products obtainable through reduction of the offal.

The fresh blood is commonly evaporated to dryness in its entirety, but in many smaller establishments it is cooked in an open kettle or vat by forcing into it live steam at rather low pressure. Steam should not be passed into the blood too rapidly, since this may result in violent boiling in spots, but should be admitted slowly enough to raise the temperature of the entire mass evenly. The temperature is held at just about the boiling point for 20 to 30 minutes, then the steam is turned off, and the contents of the vat are allowed to settle. The coagulated blood solids rise, whereas the nearly colorless blood water remains underneath. This water has little value and it seldom, if ever, pays to evaporate it. The vat is usually fitted with a screened outlet valve at the bottom for draining off the blood water. After draining, the coagulated blood solids ordinarily are pressed in a hydraulic press to remove more of the water. The resulting press cake, which still contains 45 to 50 percent of moisture, is then dried, usually in a drier of the rotary type. Steam-jacketed driers are favored, since scorching of the product, with consequent loss of the valuable nitrogen, is avoided. Ordinarily, drying of the press cake completes the process of preparing dried blood as an article of commerce. In cases of caking, grinding or screening may be required to finish the product.

PRESENT DISPOSAL OF THE REFUSE FROM SMALL-SCALE SLAUGHTER

Most of the blood from animals slaughtered on the farm is wasted, and as a rule the quantities of offal obtained are too small to justify steam rendering, or other processing which requires costly equipment, for the production of commercial fats and tankage, methods which are employed in the large abattoirs and packing houses. The offal is sometimes buried deep, but this method of disposal is laborious and entails total loss of the vaulable constituents. A more common practice is to feed the offal raw to the pigs, a practice which in general is objectionable, since the offal from diseased or parasite-infested animals is a menace to the health of the animals that eat it. Moreover, the offal attracts rats and other vermin and is conducive to the breeding of flies. For the same reasons shallow burying or plowing into the soil are not conducive to sanitation and are likely to be objectionable methods of disposal.

It was estimated in 1915, or thereabouts, that not more than one-third of the offal from retail slaughter was utilized (*4*), and although it is believed that a considerable advance in the conservation of this waste has been made since the World War, so that at present much of the refuse is satisfactorily utilized, nevertheless in the aggregate probably a large quantity of this material is not disposed of economically and efficiently. In some slaughterhouses the refuse is destroyed by incineration; in others, parts which are commercially valuable are rendered, and the remainder is incinerated. Although disposal by incineration is sanitary, it is wasteful, in that practically all the potentially valuable constituents of the animal tissues are lost. Furthermore, comparatively large quantities of fuel are required to cremate this refuse because of its high water content.

RESEARCHES ON SMALL-SCALE DISPOSAL

STEAM RENDERING

Since the dry-rendering process did not appear applicable to small-scale operations, because of the type of equipment required, no detailed experimental study of it was undertaken. One attempt to dry-render lambs' offal in an open kettle was made, but the time and attention required seemed to be prohibitive, and, moreover, grease of an inferior grade was produced.

Efforts were first directed toward devising means for simplifying and cheapening the steam processing of offal and blood with a view to adapting some form of rendering to rural or small-town conditions. A small pressure-cooking tank or steam digester (fig. 4) was constructed of standard steam-fitting supplies. It was estimated that a similar tank having a capacity of 20 gallons, sufficient to accommodate all the offal from a large steer, could have been constructed for less than $100. A 20-gallon tank is large enough for steam rendering the offal from a dozen ordinary sheep, or seven or eight 200-pound

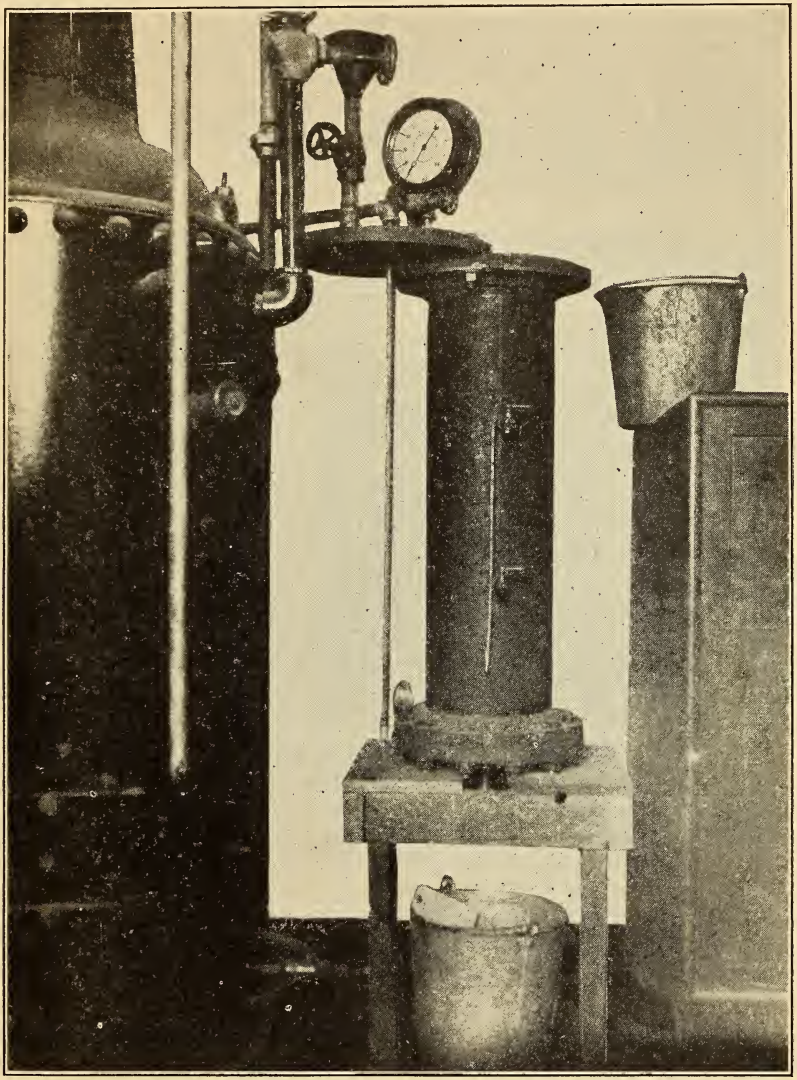

FIGURE 4.—The experimental steam-digestion tank. The top has been displaced to show the steam inlet pipe passing through the cover.

hogs. It was found that reasonably satisfactory products, grease and tankage, and yields were obtained when the offal including the waste bone from a 936-pound steer was cooked with live steam at a gage pressure as low as 20 pounds. Table 6 shows the composition of the tankage made under these experimental conditions, and of the blood solids after the blood had been coagulated with live steam. The material was analyzed after it had been dried by steam.

Rendering with live steam under sufficient pressure has the advantage that, subject to local health regulations, it is applicable to the reduction of fallen animals, that is, animals dead of disease, as well as to offal. The experimental part of the present investigation, however, dealt only with the fresh offal from presumably healthy animals slaughtered for meat.

TABLE 6.—*Composition of the dried blood and dried tankage obtained from steam-rendering the offal and blood from a steer*

Material	Yield from 1,000-pound steer	Composition [1]										
		Moisture	Ether extract (crude fat)	Crude protein (Nx6.25)	Total ash	Lime (CaO)	Nitrogen				Phosphoric acid	
							Total		Available [2]		Total (P_2O_5)	Available [3] (P_2O_5)
							(N)	(as NH_3)	(N)	(as NH_3)		
	Lbs.	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*
Dried blood	7.33	8.00	0.59	87.54	3.48	--------	14.01	(17.03)	13.56	(16.49)	0.34	0.34
Dried mixed tankage from total offal	29.48	10.00	15.80	37.76	27.90	13.06	6.04	(7.34)	5.85	(7.11)	10.92	10.53

[1] Determinations of moisture, ether extract, crude protein, and ash were made in the cattle-food laboratory, of the former Bureau of Chemistry.

[2] Determined by the official neutral permanganate method.

[3] Water-soluble, plus citrate-soluble phosphoric acid.

Steam-pressure rendering, however, is not a practicable method for the disposal or utilization of offal on the ordinary farm, or in the usual rural community. The process is dependent on the operation of a steam boiler, which requires the attention of a skilled workman and generally the value of the products would hardly compensate for the costs involved, and the skill, energy, and time required. Furthermore, the problem of drying the tankage for subsequent use as a fertilizer would still remain unless it were feasible to use the wet tankage as a feedstuff as soon as it was made.

OPEN-KETTLE RENDERING

The open-kettle rendering of offal and cooking the shed blood ordinarily is feasible on the farm. A 65-gallon farm caldron or open-kettle cooker and its stove (fig. 5) may be purchased for less than $20. The wooden cover and stovepipe cost from $1.50 to $2 additional. This outfit can be used for rendering offal, as well as for cooking feed, scalding hogs, or making soap. By cooking the total cleaned offal of thirteen 63-pound lambs in a similar open kettle, 17 pounds of crude tallow or grease and 63 pounds of wet tankage were obtained. The offal was boiled for about 6 hours, requiring 69 pounds of wood fuel. The separation of the commercially valuable crude tallow and grease was very simple; the contents of the kettle were allowed to cool overnight, and the cake of tallow and grease was lifted off the next morning.

PRESERVING WITH QUICKLIME

TEST ON TANKAGE

The tankage produced in the open-kettle experiment contained 60 percent of water, 12 percent of crude fat, 18 percent of crude protein, and 7 percent of bone phosphate of lime. It would have been valuable feeding material if used when freshly cooked. It was mixed, however, with 10 percent of its weight of crushed quicklime and allowed to dry in the air in order to produce fertilizer material (fig. 6). The mixture was spread out in a box in a shed, but as it was late fall, drying proceeded very slowly. By April 1, however, the moisture content of the quicklime and tankage mixture was reduced to 28 percent, and the material contained 3.84 percent of nitrogen, equivalent to 4.7 percent of ammonia, and 8.8 percent of bone phosphate. The weight of the added crude quicklime amounted at this time to 13 percent of the weight of the mixture. The total mineral matter or ash found by analysis amounted to 24.1 percent. No appreciable quantity of the nitrogen or ammonia originally in the tankage was lost by this air-drying with lime.

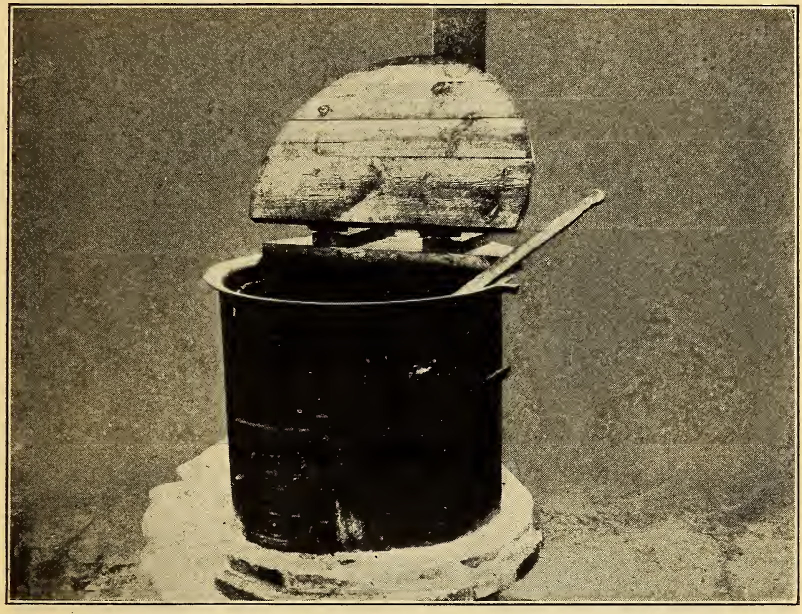

FIGURE 5.—A 65-gallon farm caldron or open-kettle cooker in its stove.

TESTS ON BLOOD

The use of crushed quicklime in the air-drying of blood has been noted by a number of authorities on fertilizers. Wheeler (*6, p. 98*), for example, stated that blood mixed with from 1.3 to 3 percent of its weight of pulverized quicklime will solidify on standing and may be air-dried readily without undergoing decomposition. This process of conserving blood for use as fertilizer was investigated. Although a test on calves' blood with 2 percent of quicklime was not successful, the results were satisfactory when 4 percent of quicklime was used. The loss of ammonia was negligible.

A large-scale experiment on air-drying the coagulum obtained by cooking about 18 gallons of hogs' blood in the open kettle was then undertaken. Approximately 120 pounds of moist coagulum (blood solids) containing about 80 percent of water and 20.6 percent of crude protein was obtained. This material was mixed with 10 percent of its weight of crushed quicklime and allowed to dry in the air under cover. After 11 weeks the mixture had a moisture content of 26.5 percent. It contained 6.5 percent of nitrogen, equivalent to 7.9 percent of ammonia, and a little more than 23 percent of ash, chiefly calcium oxide. No appreciable quantity of ammonia was lost during the drying. These experiments showed that, if admixed with crushed quicklime, animal tankage and blood in quantities produced in small-scale slaughter can be dried in the air with a reasonable degree of success, at least in cool weather.

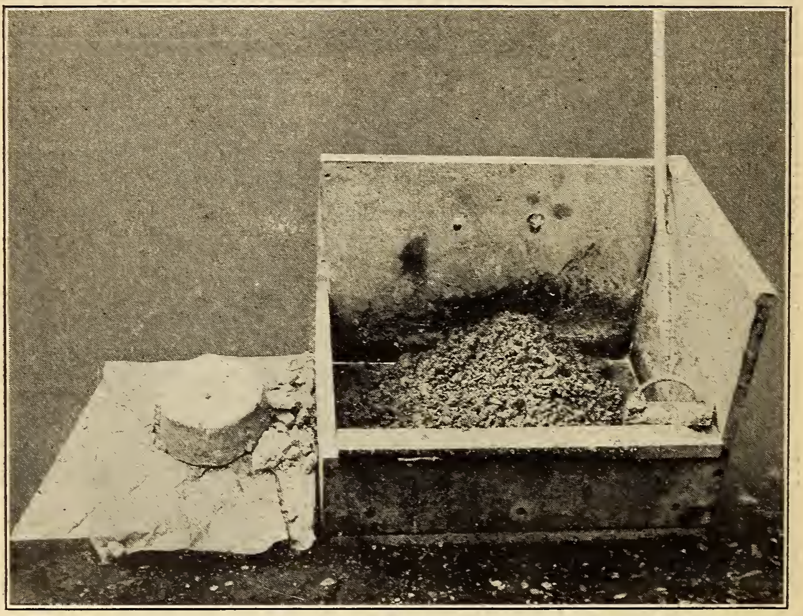

FIGURE 6.—Crude tallow (left) and cooked tankage (in box) obtained by the open-kettle cooking of the offal from lambs. The tankage has been admixed with one-tenth of its weight of quicklime.

It seemed desirable, however, to develop a process with a preservative that would conserve the valuable ammonia of the animal wastes at any season of the year and that would also accelerate the air-drying of the material more than did the quicklime. Furthermore, since for agricultural use quicklime is being replaced to some extent by hydrated lime, the fresh, lump quicklime, such as was used in the foregoing experiments, is not always readily obtainable in many localities.

AGENTS OTHER THAN QUICKLIME AS PRESERVATIVES

Attention was turned to acid-producing chemicals, as they would be more likely to conserve the ammonia of the organic material under all conditions than would an agent such as quicklime, which produces an alkaline reaction. It was realized that a satisfactory and practicable preserving agent must meet the following requisites: (1) It must be a widely distributed commodity, readily obtainable in rural districts, and comparatively cheap; (2) it must not contain a substance poisonous to man or animals, or be so dangerously corrosive as to require special equipment and training for its safe handling, and it should not have an unfavorable effect on the drying of the mixture; (3) it must be able to prevent offensive decomposition of the perishable wastes, and to conserve their ammonia, the most valuable fertilizer constituent; and if required in large quantity the agent itself should have fertilizing value; and (4) most important, the agent must be safe for growing plants, when applied in the finished mixture to the soil. In other words, no agent injurious to plant growth or deleterious to the soil could be used.

Sixteen percent superphosphate, the more concentrated superphosphates, niter cake (acid sodium sulphate), and powdered sulphur, particularly a prepared commercial sulphur inoculated with oxidizing bacteria to hasten the formation of sulphur acids, were some of the acid-producing substances that seemed to hold promise of fulfilling several of the requirements. Niter cake was not tested, however, because of its high content of unessential soda, which in this case was also undesirable.

Sulphuric acid was not considered a suitable agent because it is so corrosive that it is difficult to handle without special equipment.

EXPERIMENTS WITH SUPERPHOSPHATES AND WITH SULPHUR

A series of experiments was then undertaken to test the suitability of superphosphates (acid phosphates) of different grades, of sulphur, and of various moisture-absorbing fillers as preserving and drying agents in the conversion of animal offal, wet tankage, and blood into air-dried fertilizer material.

Although these experiments were conducted with raw offal as well as with cooked material (tankage), this should not be construed as indorsing the production of fertilizer from raw material that might contain disease-producing organisms or dangerous parasites. Since it has not been shown that treatment with the mild chemicals mentioned would safeguard the product against the spread of disease, prior cooking would be safer in all cases.

In most of the experiments 40 pounds of the refuse was thoroughly mixed with the agent being tested and spread over the bottom of a shallow bin. The compost was mixed with a rake every day or so, and the progress of the drying was followed by frequently weighing the bins.

The bins, 42 inches long, 30 inches wide, and 9 inches deep, were of wood, painted outside and waterproofed inside. They had been seasoned to constant weight before they were used.

In the trials with raw offal, the material was first hashed by being passed through an ordinary sausage chopper set for the coarsest chopping, a plate having ½- or 1-inch holes being used. Doubtless hashing with a sharpened hoe would have sufficed. Before the offal was hashed the stomachs and bladders were emptied, and from some of the material that was to be rendered later the manure was separated. Most of the manure may be removed by chopping the offal and sluicing it with water. The tankage used in the experiment was ready for mixing, since the offal had been hashed before it was rendered. In all trials with blood, the agent was added directly to the fresh whole blood, and the combination was thoroughly mixed.

The experiments were carried on at the Department of Agriculture experiment farm at Rosslyn, Va., and with the exception of a later series of investigations with small quantities of blood, they were conducted in hot weather, under conditions which constituted a severe test of the value of the various preserving agents.

TESTS ON RAW OFFAL

The first series of tests was made with the hashed raw offal from 16 hogs, amounting to approximately 7.25 percent of the live weight of the animals. It consisted of the inedible refuse other than bone wastes; it did not include the ruffle fat which is used for lard stock, or readily separable excreta.

Five 40-pound portions of the raw hashed offal were weighed into separate bins, and on the basis of 100 parts by weight of the offal the following mixtures or composts were prepared:

No. 1 was made by adding to the offal 10 parts of treble superphosphate (containing 43 percent of available phosphoric acid, which is roughly equivalent to 75 percent of pure monocalcium phosphate [4]) and 25 parts of air-dry neutral peat, as an absorbent. The mixture had the consistency of moist manure. On the basis of the weight of the complete mixture, the ingredients were as follows: Raw offal, 74.1 percent; treble superphosphate, 7.4 percent; and peat, 18.5 percent.

No. 2 comprised the offal, 5 parts of sulphur inoculated with oxidizing bacteria, and 25 parts of peat.

No. 3 consisted of the offal and 10 parts of 16-percent superphosphate (acid phosphate).

No. 4 was composed of the offal and 33⅓ parts of air-dry peat.

No. 5 at first contained only the offal and 10 parts of inoculated sulphur, but 3 days after the mixture was made 25 parts of peat were added.

The bins were placed in a ventilated shed, and every day the contents were mixed with a rake. During the first 5 days the weather was hot, in the afternoon the temperature in the shed reaching 90° F.

It was soon apparent that all the mixtures except no. 1 (fig. 7) were decomposing. Flies swarmed about the bins, and the eggs hatched, and larvae developed in the mixtures. In from 3 to 5 days the contents of all the bins except no. 1 had to be disinfected and buried. Mixtures nos. 2 and 4 were alkaline in reaction, and no. 5 was practically neutral. Mixture no. 3 was not strongly acid; its aqueous extract had an active acidity equivalent to a pH of 5.5 as shown by an empiric test designed for laboratory control.[5] This degree of active acidity (pH 5.5) is equal to 32 on the scale advocated by Wherry (*7*, *8*) for stating active acidity directly.[6] The successful mixture, no. 1, was decidedly more acid, its extract exhibiting a pH value of 5.1 or an active acidity of 79, by the test. No fly larvae developed in this material, and although eggs were laid in it, probably by house flies, none hatched. The mixture underwent a sour-smelling fermentation, but this was not pronounced and was entirely different from putrefaction. Within 3 weeks the mixture had become almost air-dry, containing approximately 11 percent of moisture. Except on 2 days, the temperature in the shed was between 80° and 90° during the day.

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[4] Monocalcium phosphate, with one mole of water of crystallization, $Ca(H_2PO_4)_2 . H_2O$.

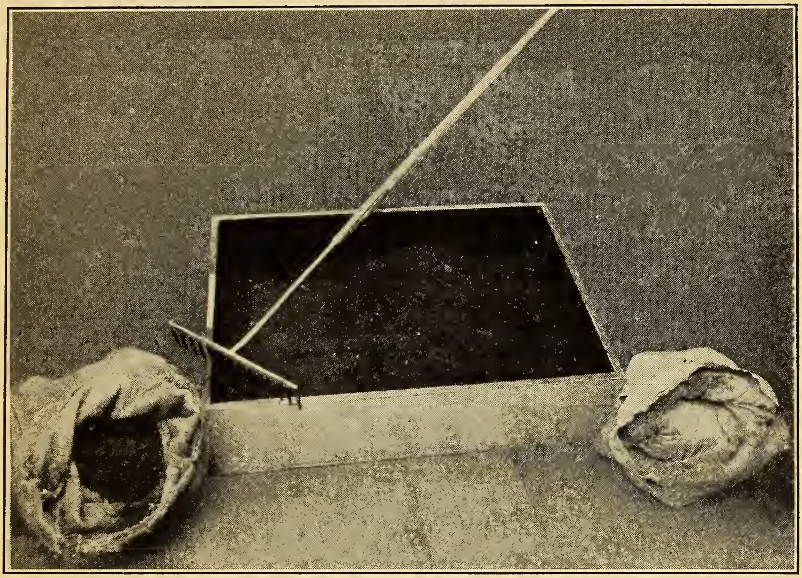

FIGURE 7.—Air-dried compost prepared from raw hogs' offal, a treble strength superphosphate (acid phosphate), and dry peat.

Four weeks after the experiment was started the successful mixture, which amounted to 25.7 pounds, was ground and packed in sacks. A sample analyzed contained moisture, 7.4 percent; grease, 23.2 percent; ash, 21.4 percent; nitrogen, 2.88 percent, equivalent to ammonia, 3.5 percent; and total phosphoric acid, 6.3 percent. The water-soluble plus citrate-soluble, or so-called "available phosphoric acid", amounted to 5.6 percent. In other words, chemical tests showed that less than 12 percent of the total phosphoric acid was insoluble or unavailable at the completion of the air-drying of the mixture. The superphosphate (acid phosphate) had served its purpose as a preservative and drying agent and yet had retained most of its fertilizing value. The analytical results on the sample of the dry product do not account for all the phosphoric acid originally present, but tne difference is slight and is probably owing to the great difficulty of obtaining a representative sample of such a mixture. The data indicate the destruction during the processing of a large quantity of the fat or grease originally in the offal but no loss of nitrogen or ammonia.

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[5] The specific, reactive acidity, or hydrogen-ion concentration, usually expressed as the pH value, was determined colorimetrically on an aqueous extract of the sample. The extract was prepared by taking out from 2 to 5 grams of the sample, adding to this 20 times as much (by weight) pure, gas-free water, allowing it to stand for 30 minutes with occasional shaking, and filtering.

[6] This method of stating the degree of acidity shows directly, on the basis of a simple numerical scale, the relative amount or concentration of active acid or hydrogen-ion in a solution, whereas the pH value is the negative of the logarithm of the concentration.

In a later series of tests with hogs' offal the successful mixture was duplicated, except that air-dry wheat chaff instead of peat was used as the moisture absorbent. Four pounds of the treble superphosphate and 15 pounds of chaff were mixed with 40 pounds of hashed raw offal. After 1 month the material was air-dry, having a moisture content of less than 9 percent. None of the nitrogen was lost, and less than 8 percent of the total phosphoric acid was in the unavailable form. Like the former mixture, this one underwent a souring fermentation, but it did not putrefy, and no flies developed.

Another 40-pound portion of similar raw material was mixed with one-third of its weight of commercial 16-percent superphosphate; no absorbent filler was used. This mixture did not putrefy, but it became very sour-smelling and remained fluid after mixtures in the same series that contained absorbent fillers had started to dry. At the end of 1 month, however, this mixture was practically air-dry. No flies developed, and no nitrogen was lost. The finished air-dry product contained 49.9 percent of ash, which fact showed that the superphosphate now amounted to almost one-half of the weight of the mixture. In the sample examined 7.7 percent of total phosphoric acid was found, about 94 percent of which was shown by chemical tests to be available. The nitrogen content was 2.2 percent, equivalent to 2.7 percent of ammonia. The quantity of fat or grease amounted to nearly 22 percent. This proportion of grease is too large for fertilizer material; undoubtedly the fertilizing value of the product would be much improved if the content of grease were smaller. Most of the grease probably could have been excluded either by rendering the fresh offal as efficiently as practicable or by separating the fatty tissues from the fresh offal before it was hashed. Of course no grease problem is involved in the processing of blood.

An attempt to preserve offal by mixing it with 10 percent of its weight of a commercial inoculated sulphur and dry chaff was not successful. In order to give the sulphur-oxidizing bacteria, with which the sulphur was inoculated, an opportunity to become active, the bulk of the sulphur was mixed with chaff and kept moist for about 10 days, after which it was dried in the air. A decided acidity developed in this mixture, but when it was added dry to the hashed offal with enough additional sulphur to give a sulphur content equal to one-tenth of the weight of the offal, it failed to prevent either decomposition or fly breeding. A water extract of the spoiled compost taken at the end of the experiment had a pH value of 6.5, equal to an active acidity of only 3; that is, the compost was nearly neutral in reaction.

TESTS ON WET OPEN-KETTLE TANKAGE

Experiments were conducted also in preserving and drying the wet tankage produced by rendering a large quantity (140 pounds) of hashed hogs' offal in an open kettle. The raw material was so fat that a single cooking and separation of the top grease after the kettle had cooled was not nearly so effective as this method had proved with the lambs' offal. Except for its high content of fat, however, the moist, freshly cooked tankage was very satisfactory material for preserving and air-drying with superphosphate (acid phosphate), more satisfactory than the raw offal. The cooked and skimmed tankage contained 61 percent of water, 17 percent of crude fat, 7 percent of ash, and 1.6 percent of nitrogen. After being admixed with one-third of its weight of 16-percent superphosphate it dried in the air sufficiently to crumble somewhat at the end of 1 week. After 4 weeks the mixture contained less than 5 percent of moisture. The finished air-dried mixture contained 46 percent of ash, 22.5 percent of crude fat, 2.3 percent of nitrogen, and 8.1 percent of total phosphoric acid, more than 94 percent of which was found by the usual chemical test to be still available. The undesirably high fat content could have been prevented by a more efficient rendering in the open kettle and several skimmings of grease.

Attempts to preserve portions of the moist open-kettle tankage with inoculated sulphur, chaff or peat being used as moisture absorbents, were not successful. Although fairly high acidity eventually developed and fly breeding was held in check, the mixtures putrefied slightly, as was indicated by the odor. The putrefactive changes resulted in pronounced destruction of fat, but there was no appreciable loss of nitrogen, probably because of the acid reaction.

TESTS ON BLOOD

The experimental work on preserving blood with acid phosphatic agents included trials both with 40-pound lots in bins and with 1-pound samples under rigid control and more exact observation in the laboratory.

LABORATORY EXPERIMENTS

The series of laboratory tests was planned to determine the minimum proportion of monocalcium phosphate, either as such or in the form of commercial superphosphate (acid phosphate) that will preserve fresh blood in a thoroughly satisfactory condition, and allow the mixture to be converted through air-drying into fertilizer material capable of being stored. In these tests the experimental mixtures were kept indoors, and although it was midwinter the temperature in the storage room most of the time ranged from 60° to 75° F.

Freshly shed hogs' blood was so manipulated as to give a uniform mixture of whole blood. Twelve portions of slightly more than 1 pound (500 grams) each were thoroughly mixed with weighed quantities of the preserving agent, sealed in jars, and taken to the laboratory. At the laboratory the weight of the mixture was ascertained, the exact proportion of agent to whole blood being thus determined; and after another thorough mixing, the charges were transferred to weighed shallow trays, the weight of each being redetermined. Throughout the period of air-drying the 12 trays were kept on a slowly rotating table in order that all the mixtures might be subjected to precisely the same temperature, humidity, and air movement. This table (fig. 8), which was about 6 feet in diameter, was rotated at a uniform rate of one revolution every 160 seconds. Since the speed at which the trays moved averaged only 5.7 feet per minute, or about one-sixteenth of a mile an hour, this rotation produced only a slight air current, which did not hasten the drying materially.

The agent used in the first 6 trays was technically pure monocalcium phosphate, containing 54.35 percent of water-soluble phosphoric acid. It was mixed with the blood in graded quantities ranging from 9.6 percent of the weight of the blood (8.75 percent of the weight of the fresh mixture) in tray no. 1 to 19.5 percent of the blood (16.3 percent of the fresh mixture) in tray no. 6.

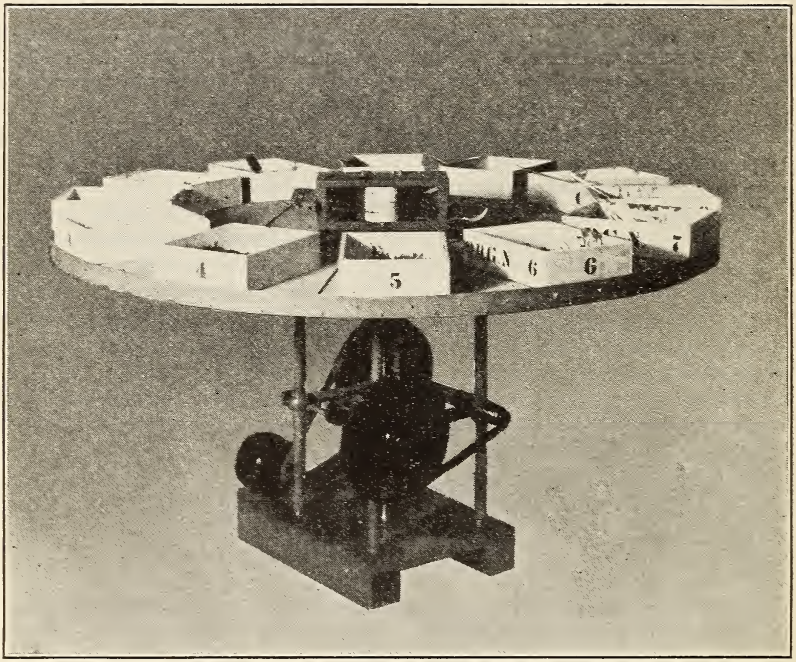

FIGURE 8.—Six-foot rotating table used to insure uniform temperature, humidity, and air movement in laboratory experiments on the preservation and air-drying of blood with superphosphates.

Trays nos. 7 to 10, inclusive, contained mixtures of blood and commercial 16-percent superphosphate [7] in quantities ranging from 29.5 percent of the weight of the blood (22.8 percent of the weight of the fresh mixture) in tray no. 7, to 46.4 percent of the blood (31.7 percent of the fresh mixture) in tray no. 10. In a sense, the last two mixtures, nos. 11 and 12, were controls, in that the agent was finely ground gypsum and no acid-reacting substance was added to the blood. The gypsum in tray no. 11 amounted to 29.3 percent of the weight of the blood, so that approximately the same quantity of gypsum per given weight of blood was in no. 11 as in no. 10, in which it had been introduced as part of the commercial superphosphate. Tray no. 12 contained approximately twice as much gypsum per given weight of blood as did no. 11.

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[7] The superphosphate used in this experiment contained 11.3 percent of water-soluble phosphoric acid (P_2O_5).

The progress of the drying was kept track of by weighing the trays almost every day. The mixtures were stirred after each weighing. Records of the temperature and relative humidity were obtained by automatic recording instruments. Frequent laboratory tests of the degree of acidity of each of the mixtures were made in order to follow any changes in reaction. After the mixtures had reached air-dryness, as was shown by no further loss in weight, they were ground, and samples were analyzed in the laboratory.

All the mixtures had reached approximate air-dryness 12 days after they were prepared. Slight additional loss in weight occurred, however, until the end of the fourth week, when constant weight was reached.

The mixtures containing the acid-phosphatic agents did not actually lose moisture more quickly than the mixtures in which gypsum alone was used, and increasing the proportion of the acid agent seemed to have no effect on the rate of drying. There was, however, a marked difference in the condition of several of the mixtures, both in fluidity and in soundness, while they remained moist. The controls, in which only gypsum was mixed with the blood, decomposed badly and remained fluid for several days, whereas the mixtures containing monocalcium phosphate, whether as the pure salt or in the form of superphosphate (acid phosphate), had at least a semisolid consistency a few hours after they were mixed, probably because of the coagulating action of the acid salt on the proteins of the blood.

The mixture in tray no. 1 gave evidence of incipient spoilage after 4 or 5 days, but decomposition did not proceed far because of the rapid drying of the material. Mixture no. 2, in which the monocalcium phosphate had amounted to 11.2 percent of the blood, gave only slight indication of decay. Trays nos. 3 to 10 displayed no evidence of spoilage. Some decomposition in no. 7 was expected, since the superphosphate in it originally amounted to only 29.5 percent of the blood, but this mixture appeared to keep perfectly, no doubt owing to its good physical condition and the rapidity with which the small quantity of material dried. Owing to the season of the year, there was no opportunity for flies to breed in this series of mixtures.

Both the monocalcium phosphate and the superphosphate produced comparatively high degrees of acidity in the mixtures, and the acidity was maintained throughout the drying period. None of the nitrogen (ammonia) originally in these mixtures was lost. The quantities of phosphoric acid converted to the unavailable state were almost negligible, the insoluble phosphoric acid being less than 3 percent of the total phosphoric acid in each of the 10 completed products in which an acid phosphate served as preserving agent.

The composition of the finished (air-dry) mixtures varied, of course, with the proportion of agent used. The nitrogen content in the first six, in which monocalcium phosphate was used, ranged from 10.36 percent in no. 1 to 7.9 percent in no. 6 (12.6 to 9.6 percent as ammonia). The content of phosphoric acid ranged from 16.4 percent in no. 1 to 26.7 percent in no. 6. The mineral constituents or ash, chiefly ignited monocalcium phosphate, which amounted to approximately 25 percent of the weight of the air-dry mixture no. 1, increased in each succeeding mixture and was 42 percent of no. 6. The moisture in each case was less than 5 percent.

The composition of the air-dry mixtures nos. 7 to 10, comprising the superphosphate series, ranged from 6.48 percent of nitrogen (7.9 percent of ammonia), 9.7 percent of phosphoric acid, and 49.8 percent of ash, in no. 7, to 4.92 percent of nitrogen (6 percent of ammonia), 11.5 percent of phosphoric acid, and 57.9 percent of ash, in no. 10.

LARGE-SCALE EXPERIMENTS

Results obtained in the large-scale experiments, in which 40-pound lots of whole blood were mixed with treble superphosphate and with 16-percent superphosphate and air-dried in hot weather, although chiefly negative in character, confirmed in the main the results obtained in the laboratory tests. For example, the trials in which the large quantities of material were air-dried (in bins under a shed) showed that commercial monocalcium phosphate to the amount of 10 percent of the weight of raw blood, or 16-percent superphosphate to the amount of 30 percent of the weight of raw blood, will not give complete satisfaction as the preserving agent in hot weather. More of the agent is needed, for example, 15 percent of the concentrated superphosphate or as much as 50 percent of the 16-percent grade would serve the purpose better.

Enough ground gypsum, dry peat, chaff, or other nonalkaline absorbent material should be used, particularly with the concentrated superphosphate, to absorb any free liquid and thereby increase the total surface, and improve the physical condition as an aid to drying.

CONCLUSIONS

By thoroughly cooking the refuse from slaughtered meat animals a wet tankage is obtained that is better and safer, either for conversion into fertilizer or for direct feeding to pigs, than is the raw offal. When steam is available, the common, industrial method of rendering with live steam is suitable if the quantity of offal is sufficient to justify the operation of steam-pressure equipment. Reasonably satisfactory products and yields are obtainable with steam at a gage pressure of 20 pounds. Ordinarily, open-kettle cooking is feasible on the farm, since kettle cookers, or caldrons, suitable for cooking or rendering the animal wastes are inexpensive and are often part of the farm equipment.

A mixture of the moist tankage or cooked blood and one-tenth of its weight of freshly burnt quicklime keeps well, at least in cool weather, and air-dries to a product suitable for fertilizer use.

The moist tankage can be converted into a product suitable for use as fertilizer and capable of being stored by mixing it immediately after cooking with not less than one-third of its weight of new 16-percent superphosphate and air-drying the mixture by spreading it in thin layers in a ventilated shed. Although superphosphate (acid phosphate) in the amount of one-third of the weight of the tankage sufficed in the experiments, in practice, at least 1 pound of superphosphate to each 2 pounds of tankage would be preferable. The tankage should not be wet enough to contain free liquid, and after being mixed with the superphosphate, the mixture should have a semisolid consistency. More concentrated forms of superphosphate, such as the double or treble superphosphate of commerce may be used, in which case not less than 10 pounds, and preferably more than 15 pounds, of the active constituent, monocalcium phosphate, for every hundredweight of the moist tankage should be used.[8] Also, it is advisable to include in the mixture enough of some nonalkaline absorbent material, such as ground gypsum, dry peat, or chaff, to stiffen it and thereby hasten drying. This process for preserving perishable tankage and offal as fertilizer has been protected by public service patent to insure its free use by any citizen of the United States (*5*).

Although hashed raw offal and blood when treated fresh can be air-dried by this process, prior cooking would be safer, since it has not been shown that the treatment with superphosphate and drying alone would render harmless, material that originally contained dangerous disease organisms or parasites.

The experiments with the raw offal showed that it is advisable to use the maximum proportion of the acid-phosphatic agent and some absorbent material. Otherwise a sour-smelling fermentation will result.

No nitrogen, or ammonia, is lost from the mixture during drying, and the decrease in fertilizing value of the acid-phosphatic agent resulting from conversion into the insoluble form is not serious. In none of the experiments did the proportion of insoluble phosphoric acid in the finished, dry mixture amount to as much as 12 percent of the total phosphoric acid.

The breeding of flies in the mixture and putrefaction of the organic material are prevented, presumably because of the acidity. The mixture dries to a stable material that can be stored and used for fertilizer as needed.

It is concluded on the basis of these experiments that refuse animal matter may be preserved and converted into comparatively stable fertilizer material by being admixed with superphosphates and absorbents. Although the amounts of superphosphates used in these tests were sufficient for experimental purposes, in practice it would be advisable to use larger proportions of the acid agents.

SUMMARY

The offal and the shed blood from the large numbers of cattle, sheep, and swine butchered on farms and in small retail establishments in the United States every year represent, in the aggregate, thousands of tons of nitrogen, or ammonia, and of phosphates, which are potentially of value as fertilizer constituents. Data are presented on yields of offal and blood to be expected from the several classes of farm animals; also on yields of tankages and grease obtainable through rendering such offal. Yields of similar products from the whole carcasses of stricken or condemned animals likewise are reported; and the reduction processes employed in large-scale operations are summarized.

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[8] From 14 to 20 pounds or more of the commercial double superphosphate (containing 40 percent or more of soluble phosphoric acid) should be used for every 100 pounds of the moist tankage.

The experiments described in this circular were undertaken with the object of developing satisfactory means of disposing of the refuse from the small-scale slaughter of meat animals. The following methods of disposal were investigated: (1) Live-steam rendering of offal; (2) open-kettle rendering of offal; (3) preserving wet tankage, raw blood, and cooked blood with quicklime for the production of fertilizer material; (4) preserving and converting into fertilizer raw offal, wet open-kettle tankage, and raw blood by mixing them with superphosphates, with and without absorbents; and (5) treating raw offal and tankage with sulphur and absorbents to preserve them for fertilizer purposes.

The offal from a steer of average size was rendered with live steam in an experimental tank of simple design. Although steam at only 20 pounds pressure was used, the yield and quality of grease and tankage obtained were reasonably satisfactory. Since steam-pressure rendering, however, is not as a rule practicable on the farm, experiments in open-kettle rendering were conducted. From these experiments it is concluded that ordinarily the open-kettle cooking of offal and blood is feasible on the farm.

The moist tankage produced in the open-kettle rendering of offal was preserved in cool weather for use as fertilizer by being mixed with one-tenth of its weight of crushed freshly burnt quicklime. The mixture dried slowly in the air without rotting, and no appreciable quantity of ammonia was lost. Similar tests on fresh blood and on cooked blood solids gave satisfactory results.

Tests of converting raw offal into products that are suitable for use as fertilizer and that can be stored, by mixing the offal with commercial grades of concentrated superphosphate and with ordinary superphosphate (acid phosphate), yielded satisfactory results when enough of the acidic agent was employed. Including in the mixtures a sufficient quantity of inert absorbent material to take up free water was found to be advisable. No specific evidence was brought out, however, to show that treating the raw offal with superphosphates and air-drying freed the product from disease-producing organisms and parasites that might be contained in the raw material; and attention is called to the fact that a preliminary cooking of the offal would be safer in all cases.

Mixtures that were prepared in hot weather and that contained double superphosphate to the amount of one-tenth of the weight of the raw offal, or 16-percent superphosphate to the amount of one-third of the weight of the raw offal, dried in the air without loss of ammonia, and only a small part of the soluble phosphoric acid originally in the mixtures was converted into the less available tribasic form. The breeding of flies appeared to be prevented by the acid condition of the mixtures, and there was no putrefactive decay, although some sour-smelling fermentation developed.

Mixtures of freshly cooked, moist tankage and the acid-phosphatic agents behaved the same as the mixtures containing the raw offal but showed little or no sour fermentation. Similar tests on raw blood showed the advisability of employing larger quantities of the preserving agents.

Attempts to utilize sulphur, sulphur inoculated with oxidizing bacteria, and absorbent material that had been moistened and incubated with inoculated sulphur, as the acid-preservative agents, were not successful.

A series of controlled laboratory tests on preserving and air-drying fresh blood mixed with monocalcium phosphate and with commercial superphosphate yielded additional data indicating the minimal proportions of the acidic agents that should be employed. Also data were obtained concerning the degree of acidity developed in the mixtures and the degree of acidity that is conducive to satisfactory results.

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